

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



Appl. No. 09/987,193  
Doc. Ref. AJ21

(11)

**EP 0 789 449 A2**

(12)

**EUROPEAN PATENT APPLICATION**

(43) Date of publication:  
13.08.1997 Bulletin 1997/33

(51) Int. Cl.<sup>6</sup>: H03D 7/12, H04B 1/26

(21) Application number: 96309090.7

(22) Date of filing: 13.12.1996

(84) Designated Contracting States:  
DE FR GB

(30) Priority: 07.02.1996 US 597755

(71) Applicant: Ford Motor Company  
Dearborn, MI 48126 (US)

(72) Inventors:  
• Whitecar, John Elliott  
Plymouth, Michigan 48170 (US)

• Hirschenberger, Frank Michael  
Brighton, Michigan 48116 (US)  
• Harris, Richard Bruce  
Plymouth, Michigan 48170 (US)

(74) Representative: Messulam, Alec Moses  
A. Messulam & Co.  
24 Broadway  
Leigh-on-Sea Essex SS9 1BN (GB)

**(54) Distortion-free switching signal mixer**

(57) An AM-modulated carrier signal is converted to a lower carrier frequency through mixing with a square wave local oscillator signal. A field-effect transistor (11) chops the modulated signal according to the square wave signal so that a chopped or sampled version of the modulated signal is created without passing the signal through a semiconductor junction. A filter (13) then selects the desired mixing product. Thus, a distortion free mixing of the signal is obtained using low cost components including a JFET switch and a square wave output from a microcontroller.

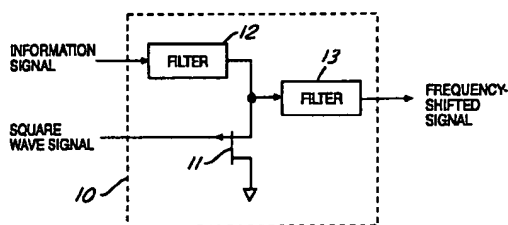


FIG.1

EP 0 789 449 A2

## Description

The present invention relates in general to a mixer for shifting an information signal in frequency, and more specifically to a low-cost chopper mixer without any distortion caused by passing the signal through a semiconductor junction.

Signal mixers are utilised in superheterodyne receivers to shift the frequency of an information signal. An original signal, such as a broadcast radio frequency (RF) signal received by an antenna, is shifted to a predetermined frequency where the information signal is filtered to remove adjacent signals and image products. A typical intermediate frequency (IF) used in an AM tuner is 450 kHz.

Audio systems, including radio receivers, are increasingly employing digital processing of audio signals to provide enhanced audio performance and low cost. In order to digitally process an analog signal such as an AM IF signal, the signal must be digitised in an analog-to-digital converter. However, the cost of an analog-to-digital converter becomes higher when high frequency analog signals are to be converted. Therefore, an AM IF signal must be first reduced in frequency to a sufficiently low value to permit easy digital conversion of the signal. However, it is not desirable to merely reduce the frequency at which the IF signal is originally produced because a higher intermediate frequency is necessary to provide proper image rejection.

Furthermore, it serves the objective of producing a low cost receiver to use the low cost integrated circuits which are available employing the standard IF frequency of 450 kHz.

In one aspect, the present invention provides a mixer for heterodyning an information signal and a square wave signal. A chopper junction receives the information signal. A field-effect transistor having first and second input/output terminals and a control terminal has its first input/output terminal connected to the chopper junction. A second input/output terminal is connected to ground, and the control terminal is connected to receive the square wave signal so that the field-effect transistor chops the information signal in accordance with the square wave. An output filter has an input coupled to the chopper junction and has a frequency characteristic for selecting a desired mixing product of the mixer. The mixer shifts the information signal and frequency without passing the information signal through a semiconductor junction.

The present invention has the advantage of providing a low cost circuit to mix a relatively high intermediate frequency to a down-converted intermediate frequency without introducing distortion into the information signal. In the case of a digital radio receiver, lower cost analog-to-digital converters can be employed to digitise the down-converted intermediate frequency, while using a minimum number of additional parts.

The invention will now be described further, by way of example, with reference to the accompanying draw-

ings, in which:

Figure 1 is a block diagram showing a chopper based mixer according to the present invention, Figure 2 shows an information signal prior to mixing.

Figure 3 shows a square wave mixing signal, Figure 4 shows a chopped information signal, Figure 5 shows a frequency-shifted information signal after the chopped signal is lowpass filtered, Figure 6 shows a block diagram of a radio receiver incorporating the present invention, and Figure 7 is a schematic diagram showing the chopper-based signal mixer of the present invention in greater detail,

Fig. 1 shows a signal mixer 10 receiving an information signal as an input and producing a frequency shifted signal as an output. The mixing function is performed without creating distortion because the information signal is never passed through any semiconductor junction which would otherwise be a source of distortion. Instead, a P-channel junction field effect transistor (JFET) "chops" or "samples" the information signal according to a square wave signal which performs the function of a local oscillator signal. The JFET has first and second input/output terminals approximating a switch to produce either a near open circuit or a near short circuit between the terminals.

Mixer 10 includes a JFET 11. The information signal is passed through a passive attenuator/filter 12 and is coupled to the source terminal of JFET 11. The gate terminal of JFET 11 is coupled to the square wave local oscillator signal. The drain terminal of JFET 11 is connected to ground. JFET 11 is a P-channel JFET in the illustrated embodiment, although other types of FETs can be used. The source terminal of JFET 11 is further connected to the input of a lowpass-filter 13.

In operation, JFET 11 is switched on and off by the square wave signal which chops the information signal at the rate of the square wave signal. Thus, the mixer effectively multiplies the information signal with a square wave having a value of "1" when the JFET is off and "0" when the JFET is on, thereby producing signals at the sum and difference frequencies as in any mixing operation. In the present invention, mixing is performed without passing the signal through any semiconductor junction. The output signal is then passed through filter 13 so that only the desired mixing product (e.g., the difference signal) is passed to the output of the mixer.

In a digital system, a square wave oscillator signal is easily producible at almost any desired frequency, for example, a microprocessor clock circuit may provide the basis for an appropriate oscillator signal. Mixing circuit 10 can thus be implemented at low cost since only a few simple components are required.

Fig. 2 shows an amplitude modulated information signal prior to input to the mixer. For example, an AM IF signal may have a frequency of 450 kHz and a variable

amplitude which encodes the information (e.g., audio signal) as shown by the signal envelope.

Fig. 3 shows a square wave signal for mixing with the information signal of Fig. 2. The square wave signal has a 50% duty cycle and has a frequency different from the frequency of the information signal by an amount equal to the desired final frequency of the frequency shifted signal. For example, a local oscillator square wave signal of 459.5 kHz can be used to produce a frequency-shifted signal at 9.5 kHz.

Fig. 4 illustrates the chopped information signal appearing at the source terminal of JFET 11 in Fig. 1. When JFET 11 is off, the chopped signal in Fig. 4 equals the original information signal. When JFET 11 is on, the signal in Fig. 4 equals approximately 0 volts due to a low impedance connection to ground through JFET 11 and due to the front end impedance provided by filter 12.

Fig. 5 shows the frequency-shifted signal after output filtering in filter 13 so that the frequency shifted signal encodes the same information envelope but using a much lower carrier frequency. Thus, the analog frequency-shifted signal can be more easily digitised for digital signal processing.

A radio receiver incorporating the present invention is shown in Fig. 6. An antenna 20 picks up broadcast signals and provides an RF signal to an analog tuner 21. For example, the RF signal may be an AM broadcast signal and analog tuner 21 may include a double-mixing AM tuner providing an AM IF output at 450 kHz. The AM IF signal is provided to a chopper mixer 22 for down-conversion. A microcontroller 23 which controls operation of the receiver co-ordinates operation of analog and digital radio functions. Microcontroller 23 further includes a pulse width modulated (PWM) output for providing a square wave signal at any selectable frequency. In the preferred embodiment, the PWM square wave signal has a 50% duty cycle and a frequency of 459.5 kHz.

A down-converted IF signal having a frequency of 9.5 kHz is provided from chopper mixer 22 to the input of an analog-to-digital (A/D) converter 24. A digitised or sampled version of the down-converted IF is provided to a digital signal processor (DSP) 25 that performs demodulation of the down-converted and digitised AM IF signal. DSP 25 may also provide stereo detection, such as CQUAM demodulation. The recovered information signal is provided from DSP 25 to the input of a digital-to-analog (D/A) converter 26 for producing left and right and front and rear audio signals.

Chopper mixer 22 is shown in more detail in Fig. 7. Input filter 12 receives a 450 kHz IF signal at its input terminal 30. A highpass filter comprising capacitors 31 and 34 and resistors 32, 33, and 35 reject undesirable audio frequency components coming from the analog tuner. A series resistor 36 provides an impedance of about 30K ohms to provide attenuation and isolation between JFET 11 and the analog tuner (and more specifically to provide isolation between the local oscillator

square wave signal and the tuner). Thus, the output of resistor 36 is connected to the source terminal of JFET 11. The output of resistor 36 is also coupled to ground through a bias resistor 37.

The gate terminal of JFET 11 receives the square wave PWM mixing signal via a terminal 40. A bias resistor 41 is coupled between the gate terminal and ground.

The chopped output signal appearing at the source terminal of JFET 11 is provided to the input of post-mixer filter 13 through a coupling capacitor 45. Filter 13 is preferably comprised of a two-stage active lowpass filter including a pair of op amps 46 and 47. The non-inverting input of op amp 46 receives the chopped information signal plus a bias voltage received through a resistor 48 coupled to a fixed voltage of +5 volts. The inverting input of op amp 46 likewise receives a fixed +5 volt bias through a resistor 50. A feedback resistor 51 and a feedback capacitor 52 are connected in parallel from the output of op amp 46 to the inverting input of op amp 46. Power is supplied to op amp 46 at the junction of a resistor 53 and capacitor 54 which are connected between a +10 volt supply and ground.

The output of op amp 46 is coupled to the inverting input of op amp 47 through a coupling resistor 55. The non-inverting input of op amp 47 is connected to a +5 volt supply. Feedback resistor 56 and feedback capacitor 57 are connected in parallel between the output of op amp 47 and the inverting input of op amp 47. The output of op amp 47 is RC filtered by a resistor 60 and a capacitor 61.

Active filter 13 filters off bleed-through of local oscillator signals included in the JFET output signal and filters off unwanted mixing products. An active filter is utilised in order to provide signal gain in order to match the dynamic range of the output signal with the dynamic range of the A/D converter. Thus, an AM IF signal of 450 kHz has been down-converted to an AM IF signal of 9.5 kHz.

## Claims

1. A mixer for heterodyning an information signal and a square wave signal, comprising:

a chopper junction (12) receiving said information signal;

a field-effect transistor (11) having first and second input/output terminals and a control terminal, said first input/output terminal being connected to said chopper junction (12), said second input/output terminal being coupled to ground, and said control terminal being connected to receive said square wave signal so that said field-effect transistor (11) chops said information signal in accordance with said square wave;

an output filter (13) having an input coupled to said chopper junction, said output filter (13) having a frequency characteristic for selecting

a desired mixing product of said mixer; and  
whereby said mixer (10) shifts said information  
signal in frequency without passing said infor-  
mation signal through a semiconductor junc-  
tion.

5

2. A mixer as claimed in claim 1, wherein said square  
wave signal switches said field-effect transistor  
between fully-on and fully-off states with a 50%  
duty cycle. 10
3. A mixer as claimed in claim 2, wherein said square  
wave signal is generated under microprocessor  
control. 15
4. A mixer as claimed in any preceding claim, wherein  
said information signal is shifted down in frequency  
and wherein said output filter is comprised of a sec-  
ond-order low pass filter. 20
5. A broadcast radio receiver comprising: an interme-  
diate frequency (IF) section generating an IF signal  
from a radio frequency (RF) broadcast signal;  
a chopper junction receiving said IF signal;  
oscillator means for generating a square wave sig-  
nal having a fixed frequency not equal to a fre-  
quency of said IF signal; 25  
a field-effect transistor having first and sec-  
ond input/output terminals and a control terminal,  
said first input/output terminal being connected to  
said chopper junction, said second input/output ter-  
minal being coupled to ground, and said control ter-  
minal being connected to said oscillator means to  
receive said square wave signal so that said field-  
effect transistor chops said IF signal in accordance  
with said square wave; 30  
an output filter having an input coupled to  
said chopper junction, said output filter having a fre-  
quency characteristic for selecting a down-con-  
verted IF signal; 40  
an analog-to-digital converter digitising said  
down-converted IF signal; and  
a digital signal processor demodulating said  
down-converted IF signal. 45
6. A receiver as claimed in claim 5, further comprising  
a conditioning circuit providing isolation between  
said IF section and said chopper junction.
7. A receiver as claimed in claim 5 or 6, wherein said  
output filter is comprised of a second-order low  
pass filter. 50
8. A receiver as claimed in claim 5, 6 or 7, wherein  
said oscillator means is comprised of a microproc-  
essor generating said square wave signal from a  
pulse width modulated output circuit. 55
9. A receiver as claimed in any one of claims 5 to 8,

wherein said field-effect transistor is comprised of a  
P-channel JFET.

10. A method of shifting the frequency of an information  
signal, comprising the steps of:

generating said information signal having a first  
frequency;  
applying said information signal to a chopping  
junction;  
generating a square wave signal having a sec-  
ond frequency, said square wave signal oscil-  
lating between first and second voltages  
substantially at a 50% duty cycle;  
chopping said information signal in response to  
said square wave signal by shunting said infor-  
mation signal to ground when said square  
wave signal is at said first voltage and isolating  
said information signal from said ground when  
said square wave signal is at said second volt-  
age; and  
filtering said chopped information signal to  
select said information signal at a shifted fre-  
quency.

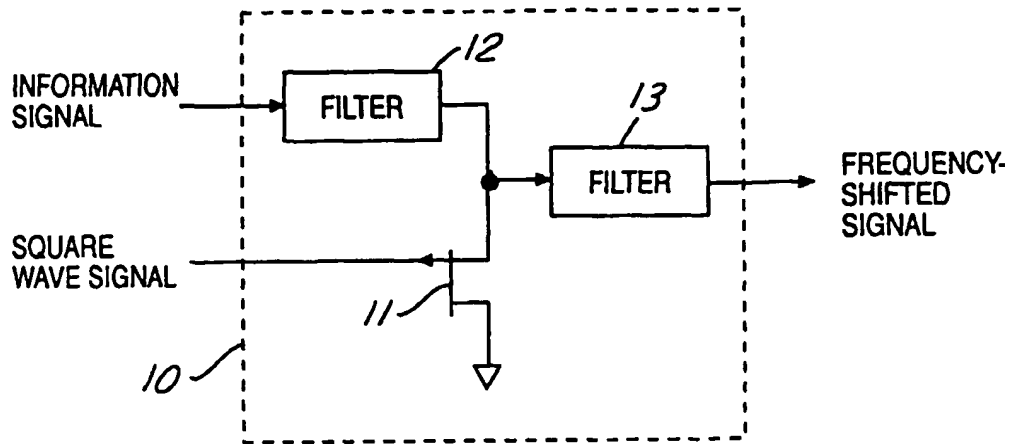


FIG. 1

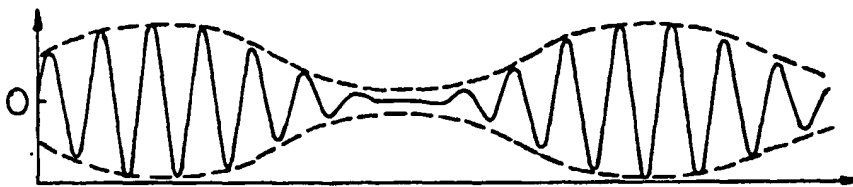


FIG. 2

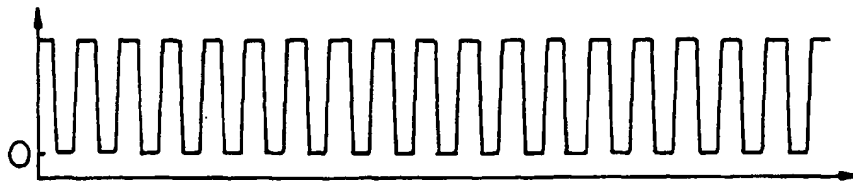


FIG. 3



FIG. 4

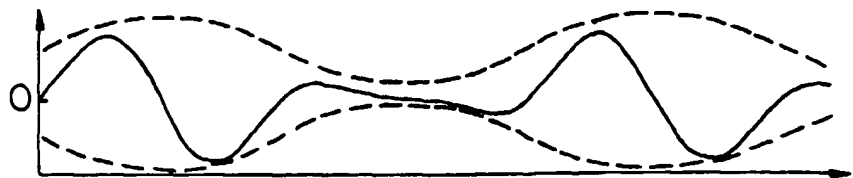


FIG. 5

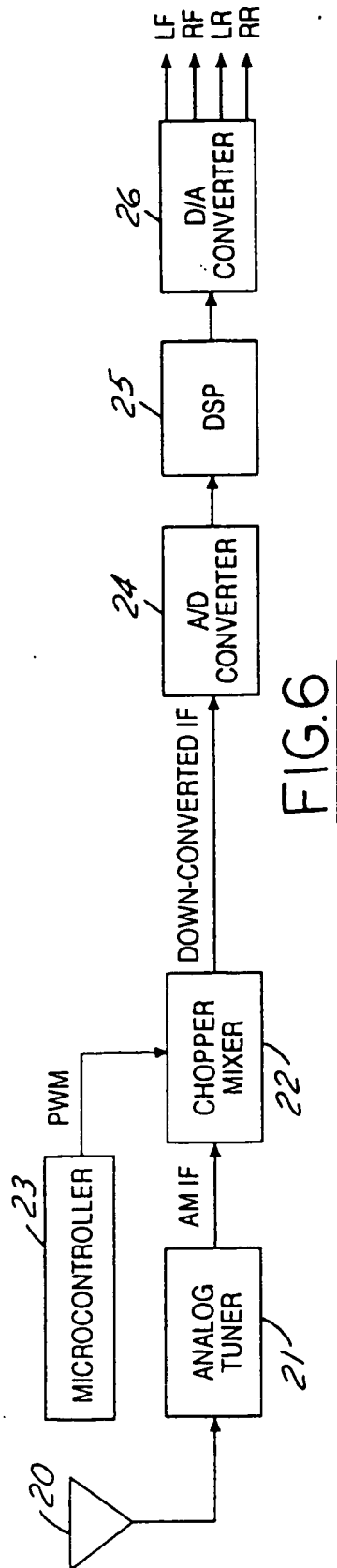


FIG. 6

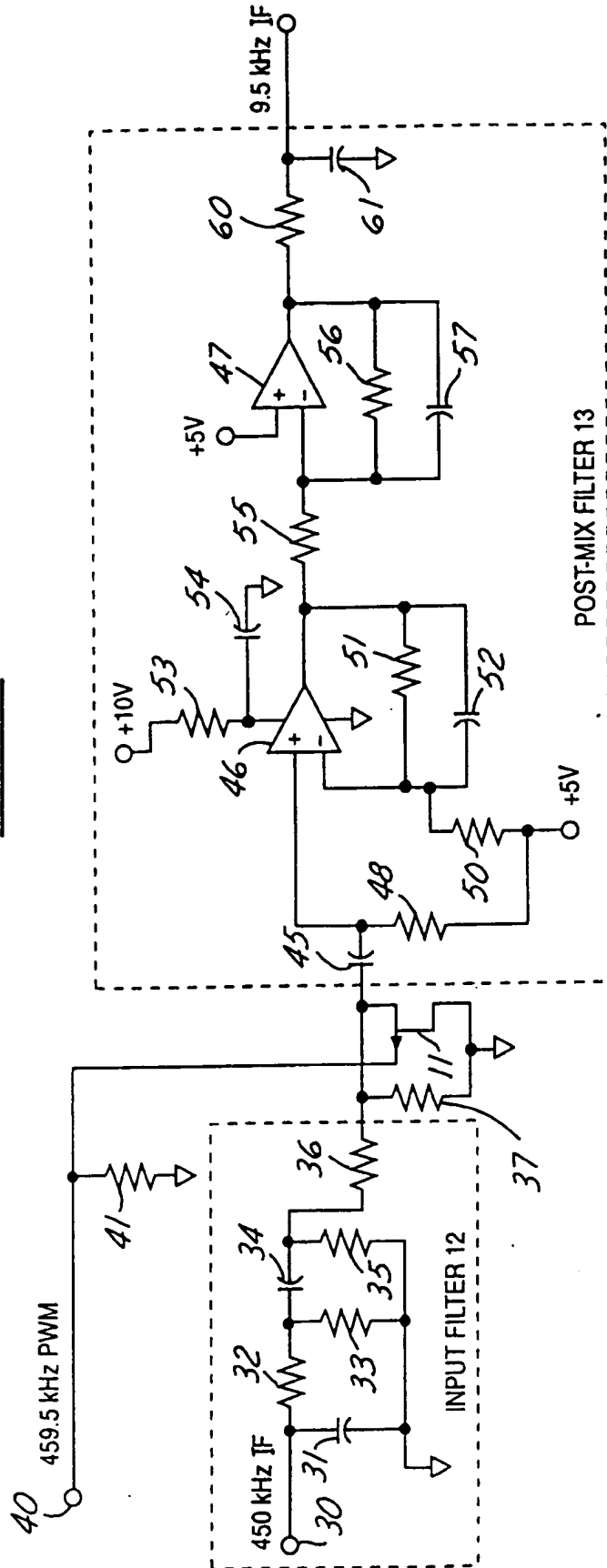


FIG. 7

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

**EP 0 789 449 A3**

(12)

**EUROPEAN PATENT APPLICATION**

(88) Date of publication A3:  
14.07.1999 Bulletin 1999/28

(51) Int. Cl.<sup>6</sup>: H03D 7/12, H04B 1/26

(43) Date of publication A2:  
13.08.1997 Bulletin 1997/33

(21) Application number: 96309090.7

(22) Date of filing: 13.12.1996

(84) Designated Contracting States:  
DE FR GB

(30) Priority: 07.02.1996 US 597755

(71) Applicant: Ford Motor Company  
Dearborn, MI 48126 (US)

(72) Inventors:  
• Whitecar, John Elliott  
Plymouth, Michigan 48170 (US)

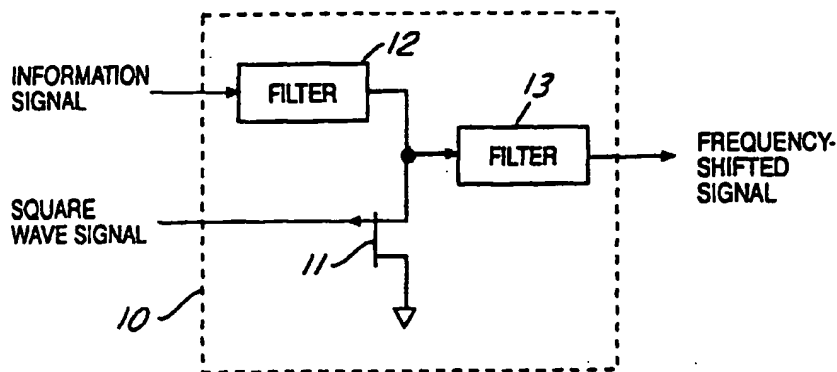
• Hirschenberger, Frank Michael  
Brighton, Michigan 48116 (US)  
• Harris, Richard Bruce  
Plymouth, Michigan 48170 (US)

(74) Representative:  
Messulam, Alec Moses  
A. Messulam & Co.  
24 Broadway  
Leigh-on-Sea Essex SS9 1BN (GB)

**(54) Distortion-free switching signal mixer**

(57) An AM-modulated carrier signal is converted to a lower carrier frequency through mixing with a square wave local oscillator signal. A field-effect transistor (11) chops the modulated signal according to the square wave signal so that a chopped or sampled version of the modulated signal is created without passing the signal

through a semiconductor junction. A filter (13) then selects the desired mixing product. Thus, a distortion free mixing of the signal is obtained using low cost components including a JFET switch and a square wave output from a microcontroller.



**FIG. 1**

EP 0 789 449 A3



European Patent  
Office

# EUROPEAN SEARCH REPORT

Application Number  
EP 96 30 9090

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A	EP 0 590 191 A (SIEMENS AG) 6 April 1994 * column 1, line 52 - column 2, line 16; figure 1 *	1 5,10	H03D7/12 H04B1/26
X	YHLAND K ET AL: "A NOVEL SINGLE DEVICE BALANCED REESISTIVE HEMT MIXER" IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM DIGEST, ORLANDO, MAY 16 - 20, 1995, vol. 3, 16 May 1995, pages 1411-1414, XP000552972 KIRBY L (ED ) * figure 1 *	1	
A	EP 0 087 336 A (THOMSON CSF) 31 August 1983 * figures 1,7 *	1,5,10	
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			H03D
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>21 May 1999</b>	Examiner <b>Peeters, M</b>
<p><b>CATEGORY OF CITED DOCUMENTS</b></p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons &amp; : member of the same patent family, corresponding document</p>			

EPO FORM 1503 (02.92) (P4/C01)



**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 96 30 9090

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

21-05-1999

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0590191 A	06-04-1994	DE 59209454 D	17-09-1998
		JP 6204751 A	22-07-1994
		US 5465419 A	07-11-1995
EP 0087336 A	31-08-1983	FR 2521784 A	19-08-1983
		JP 58184829 A	28-10-1983
		US 4490854 A	25-12-1984

**This Page is Inserted by IFW Indexing and Scanning  
Operations and is not part of the Official Record**

**BEST AVAILABLE IMAGES**

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: \_\_\_\_\_

**IMAGES ARE BEST AVAILABLE COPY.**

**As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.**